WATER RESOURCE AVAILABILITY IN THE ST. JOSEPH RIVER BASIN, INDIANA

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

Water Resource Assessment 87-1

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SELECTED LIST OF ACRONYMNS AND ABBREVIATIONS

FDA	Food and Drug Administration
GWRSC	Governor's Water Resource Study Commission
IAC	Indiana Administrative Code
IC	Indiana Code
IDNR	Indiana Department of Natural Resources
IDEM	Indiana Department of Environmental Management
MACOG	Michiana Area Council of Governments
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
SCS	U.S. Soil Conservation Service
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

$^{\circ}F$	degrees Fahrenheit
ft^3/s	cubic feet per second
mi^2	square miles
m.s.l.	mean sea level
mg/l	milligrams per liter

app.	appendix
fig.	figure
pl.	plate

GEOLOGIC FRAMEWORK

Topography, geology and soils affect the availability of surface- and ground-water resources. These factors largely determine the proportion of precipitation which runs off the land to become surface water, as opposed to that which infiltrates into the soil and percolates through underlying materials to become ground water.

The geologic timescale (fig. 6) illustrates the sequence of geologic events for Indiana and the rock types associated with each geologic period. During the Pleistocene Epoch (Ice Age), glacial lobes repeatedly entered Indiana. The glacial lobes entered the state from at least two directions: from the northeast out of the Lake Erie and Saginaw Bay basins, and from the northwest out of the Lake Michigan basin (fig. 7). Advancing glaciers scoured the land surface while retreating glaciers left behind large deposits of scoured materials. Erosion has subsequently modified the glacial deposits to produce currently existing landforms.

This glacial and post-glacial activity has been the predominant influence upon the present topography and surficial geology of the St. Joseph River basin. Glacial deposits, some as thick as 450 feet (fig. 8), cover the basin bedrock as a legacy of the most recent period of glaciation. Land surface elevation ranges from 665 feet m.s.l. (mean sea level) near South Bend to 1205 feet m.s.l. north of Angola. Local topographic relief in areas containing kame deposits may exceed 200 feet.

ERAS	PERIODS	APPROXIMATE LENGTH IN YEARS	ROCK TYPES IN INDIANA
CENOZOIC	QUATERNARY (PLEISTOCENE EPOCH)	1 MILLION	Glacial drift till gravel sand silt (including loess), clay marl and peat (Till and gravel contain boulders of many kinds of sedimentary igneous and metamorphic rocks) Thickness 0-500 ft
CENOZOIC	TERTIARY	60 MILLION	Cherty gravels / Sand and clay — Scattered deposits
MESOZOIC	CRETACEOUS / JURASSIC / TRIASSIC	70 MILLION / 35 MILLION / 30 MILLION	No deposits in Indiana
PALEOZOIC	PERMIAN	25 MILLION	No deposits in Indiana
PALEOZOIC	PENNSYLVANIAN	20 MILLION	Shale (including carbonaceous shale) mudstone sandstone coal clay limestone and conglomerate 1 500 ft
PALEOZOIC	MISSISSIPPIAN	20 MILLION	Upper Part alternating beds of shale sandstone and limestone 500 ft
			Middle Part limestone dolomite beds of chart and gypsum 300 ft
			Lower Part shale mudstone sandstone and some limestone 600 ft
PALEOZOIC	DEVONIAN	60 MILLION	Upper Part: carbonaceous shale 100 ft
			Lower Part limestone dolomite a few sandstone beds 40 80 ft
PALEOZOIC	SILURIAN	40 MILLION	Dolomite limestone chert siltstone and shale 100 300 ft
PALEOZOIC	ORDOVICIAN	70 MILLION	Shale limestone and dolomite 700 ft.
			Limestone dolomite and sandstone — Not exposed at the surface in Indiana
PALEOZOIC	CAMBRIAN	80 MILLION	Sandstone and dolomite — Not exposed at the surface in Indiana
	PRECAMBRIAN ERAS	3 BILLION	Granite marble, gneiss and other igneous and metamorphic rock types — Not exposed at the surface in Indiana

Figure 6. Geologic Timescale for Indiana

TOPOGRAPHY

The St. Joseph River basin is characterized by complex topographic features that include moraines having rugged topography and relatively level till plains interspersed among braided meltwater (outwash) channels and hummocky ridges. This terrain includes small enclosed basins occupied by lakes or marshes, as well as broad pitted outwash fans. Simpler topographic features include the broad, level till plain of the Wakaruska-Wyatt-Nappanee area and the wide coalesced outwash surfaces of the St. Joseph River valley itself. The basin's topographic complexity suggests the complexity of distribution of Quaternary sediment types, which in turn relates to the complex glacial history.

The basin can be subdivided into six regions on the basis of topography and distribution of surface sediments. The southern margin of the basin is defined by the combined Mississinewa and Packerton Moraines (fig. 9, region 1). The southwestern part of the moraines is characterized by sag and swell topography having as much of 40 feet of relief. There are many lakes in the northwestern part of the morainal area, many of which are more than 50 feet deep. Sediments within these moraines consist of a heterogeneous assemblage of both clayey basal melt-out and flow tills of the Lagro Formation, sand and gravel outwash, and lake muds juxtaposed both vertically and laterally.

The northwestern flank of the morainal area is cut by open channel heads and probable collapsed ice trough cut into till (fig. 9, region 2, white pattern). The channels trend at right angles away from the morainal area and coalesce into an apron. Some channels remain active, especially those that are part of the channel system of the main tributaries within the St. Joseph River basin. The channels are filled with outwash sand and gravel that is overlain in places by organic muds and peat. The presence of closed basins within the St. Joseph basin suggests that the original longitudinal profiles of the channels have been disturbed by events subsequent to channel formation.

Northwest of the previously mentioned apron, the outwash channels coalesce to form broad outwash plains that are laterally extensive along the moraine front (fig. 9, region 3). The outwash deposits are interrupted locally by hummocky ridges of morainal material and ice-contact deposits. These outwash materials are inset within remnants of the loamy till that underlie the more clayey tills in the moraines of the Erie Lobe.

Outwash deposits extend northwestward and northward into a broad lowland that can be subdivided into two parts. The northeastern part (fig. 9, region 4a) has a complex array of gravel-filled outwash channels, ground moraine composed of loamy till, and hummocky ridges that may represent minor moraines and/or ice-contact deposits of the Saginaw Lobe. The southwestern part (fig. 9, region 4b) is characterized by larger outwash channels that are now valleys of major tributaries of the St. Joseph River, including the Elkhart, Little Elkhart and Pigeon Rivers.

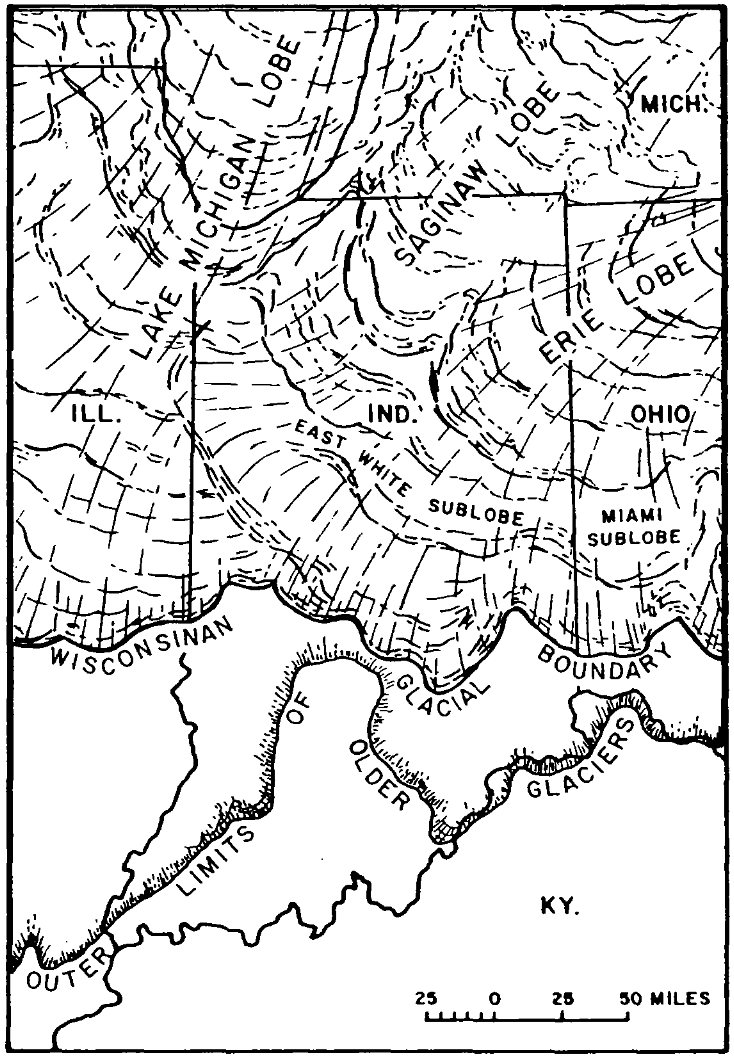

Figure 7. Major Ice Lobes during Wisconsinan Age

The lowland to the southwest, however, is occupied by a more extensive plain that is cut by few channels (fig. 9, region 5). Only the northern part of this till plain lies within the St. Joseph River basin. The plain is bounded on the west by the Maxinkuckee Moraine, which has been considered to be the terminal moraine of the Saginaw Lobe and which possesses rugged topography with numerous closed basins.

The Kankakee Lowland (fig. 9, region 6), is a broad, flat region that extends from Illinois, across northwestern Indiana, and into southwestern Michigan. That part of the lowland extending southwestward from South Bend is now the floodplain of the Kankakee River. That part extending east of South Bend is now occupied by the St. Joseph River. The lowland forms an exceptionally level plain covered by fine-grained Holocene alluvium that is underlain by thick outwash sand and gravel which in turn overlie lake muds.

Soils in the St. Joseph basin generally fall within one of three classes: 1) sandy or loamy soils developed on outwash and allumium; 2) silty or clayey soils developed on till; and 3) muck soils developed in depressional wetland areas. Descriptions of soil associations are given in app. 3.

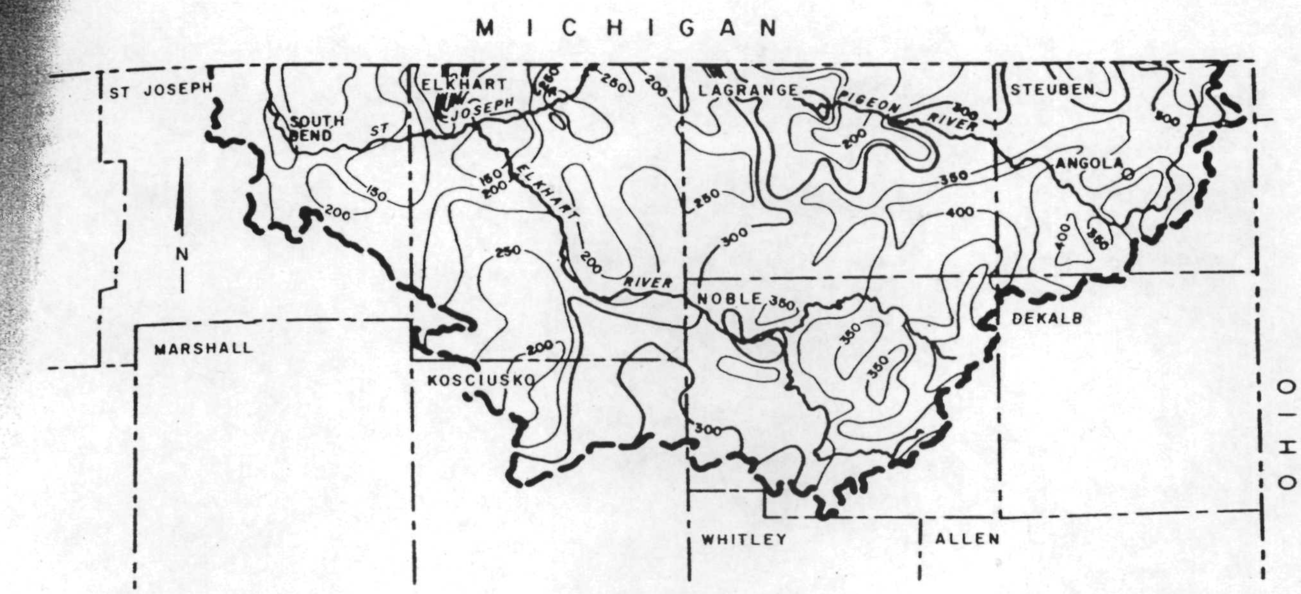

Figure 8. Thickness of Unconsolidated Materials

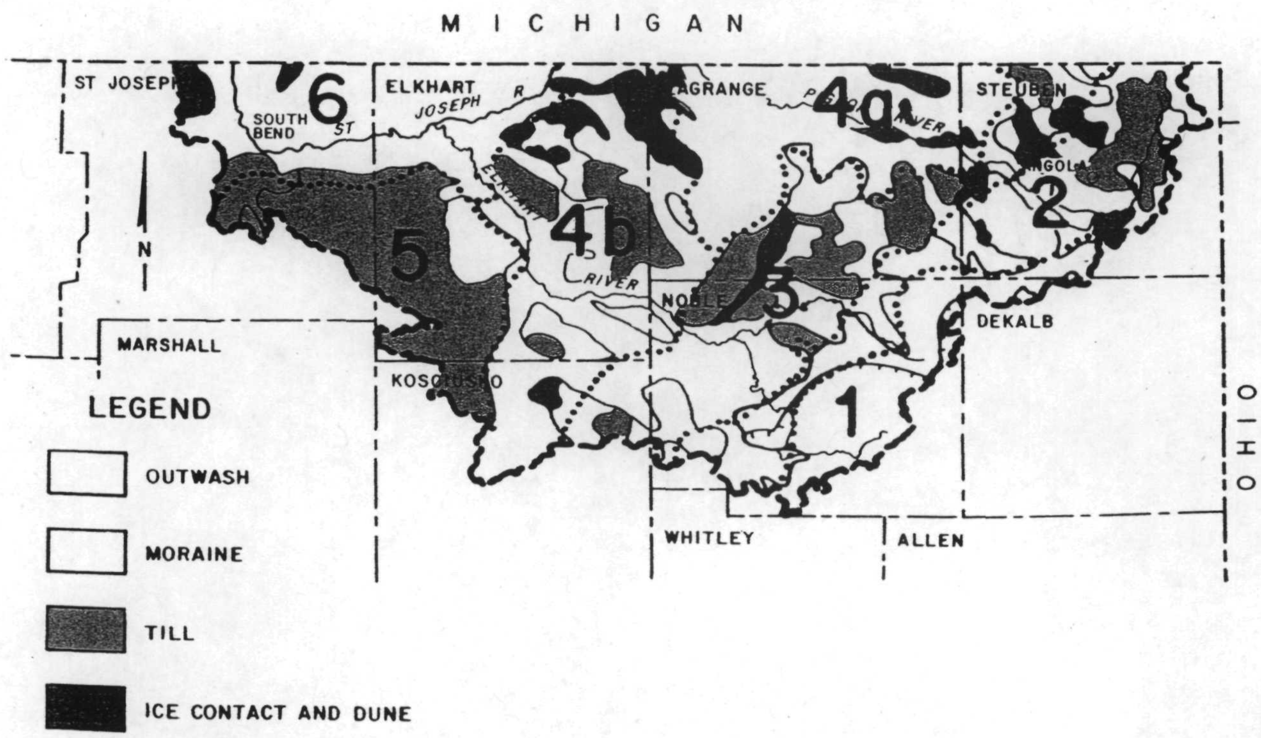

Figure 9. Geomorphic Regions

GLACIAL GEOLOGY

The surficial geology of the St. Joseph River basin reflects a very complex glacial history. Interpretations of geomorphology and soils have resulted in revised mapping of surficial materials (Gray, in preparation). Insights from this mapping, combined with knowledge from existing geologic and topographic maps, have yielded a hypothesized sequence of glacial events in the St. Joseph basin.

This hypothesis, which includes a concept presented as early as 1883 that northeastern Indiana is an area of interlobate relationships, assumes that the present topography is entirely of Wisconsinan age materials. (Little is known of relationships of earlier glacial material due to a lack of subsurface stratigraphic data.)An outline of the hypothesized events is presented in table 2 and related to the map in fig. 10.

TABLE 2.
Relationships of Quaternary Stratigraphic Units and Hypothesized Glacial and Drainage Events

		GLACIAL LOBE			
FORMATION MEMBER	LAKE MICHIGAN	EASTERN UNDIFF.	ERIE	SAGINAW	DRAINAGE ROUTE
Largo Fm.		Clayey till southern Noble Co. (event 6)			Northeast to the St. Joseph and Kankakee rivers through pre-existing troughs
Wedron Fm.	Ice-contact proximal fans, tectonic struc-tures(?), southern St. Joseph valley margin (event 5)				Southward, down pre-existing troughs to the Tippecanoe and Wabash rivers
Trafalgar Fm., upper tongue			Loamy tills and ice-contact deposits; exemplified by the Ligonier-Topeka-LaGrange line of ice contact deposits (event 4)		Northeast to the St. Joseph and Kankakee rivers through pre-existing troughs; exempli-fied by the massive fan at Topeka
unassigned				Sandy and clayey tills of uplands, Elkhart, LaGrange counties (event 3)	Westward as ice-prominal fans on uplands; ice-frontal lateral drainage in troughs between ice (on northeast) and ice-contact slopes (on southwest), northwestward to St. Joseph and Kankakee rivers
unassigned		Sandy tills of Nappanee area westward (event 2)			(ice covered)
Wedron Fm., Snider Till Mb.	Clayey till, subsurface of Wyatt area (event 1)				Eastward, up St. Joseph River, thence south (routes unknown) to Wabash River

AGE

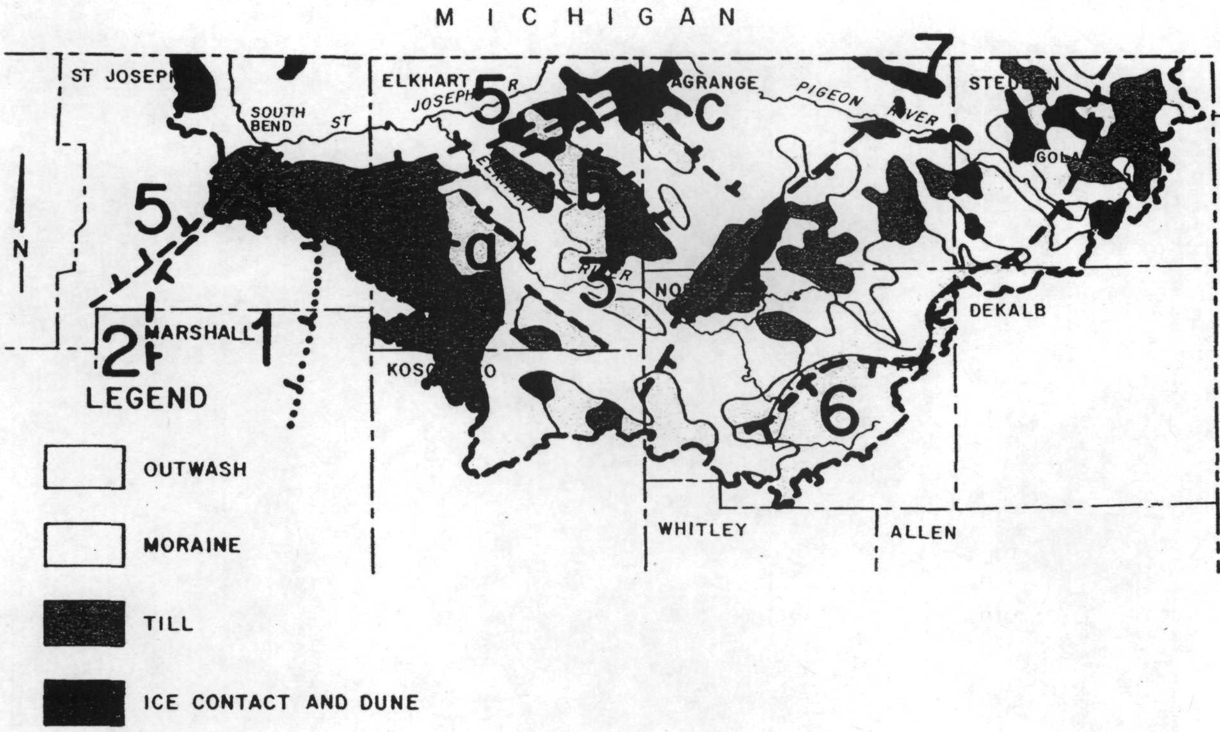

Figure 10. Sequence of Wisconsinan Glacial Events

BEDROCK GEOLOGY

The bedrock underlying the St. Joseph River basin in Indiana consists mainly of layered Paleozoic limestone, dolomite, sandstone, siltstone and shale, which represent deposits of ancient inland seas. Beneath these rocks are Precambrian igneous basement rocks composed mainly of granite, basalt and arkose. All of these rocks are deformed regionally to form the Kankakee and Cincinnati Arches (fig. 11), which together are a bedrock structural high that extends from northwestern through southeastern Indiana. Along the northern side of this high, including the St. Joseph basin, the sedimentary formations dip about 30 feet per mile to the northeast into the major structural feature called the Michigan Basin. The rocks at the bedrock surface become progressively younger toward the northeast.

Bedrock is covered by a thick mantle of glacial drift and does not appear at the modern land surface anywhere in the drainage basin. Therefore, knowledge of bedrock is based on logs of exploratory drilling, mostly for oil and gas.

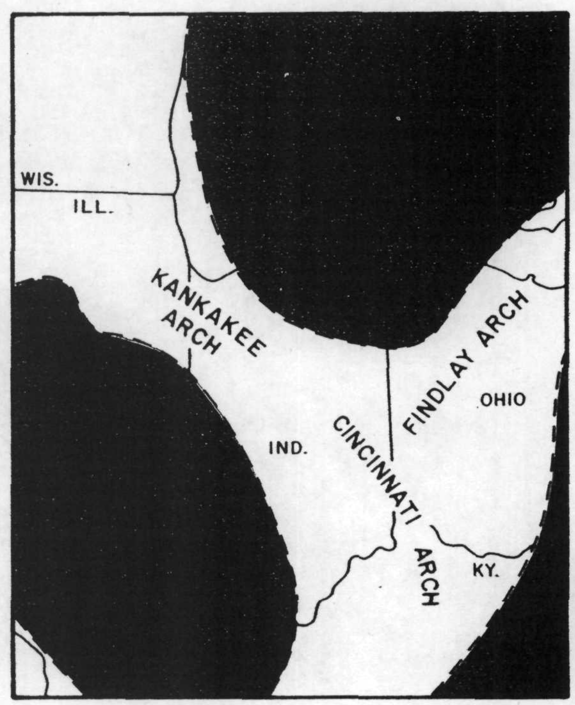

Figure 11. Regional Geologic Structure

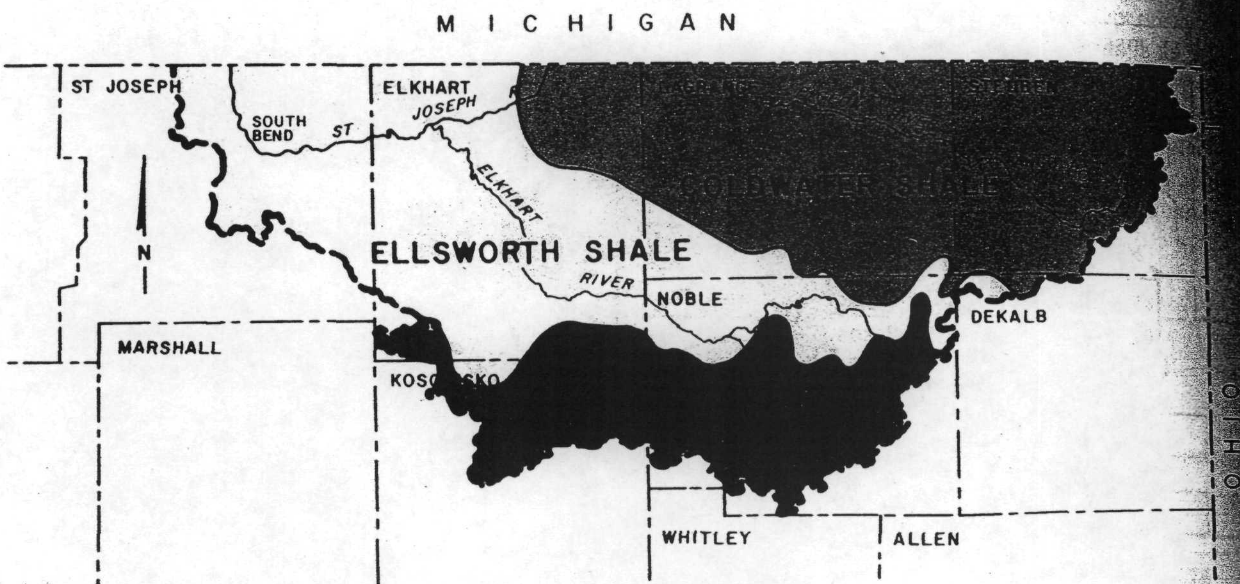

Figure 12. Areal Distribution of Bedrock Units

An exploratory well in Steuben County provides an exemplary section of bedrock formations in that part of the basin where the sedimentary bedrock section is thickest. Here, 450 feet of glacial material overlies about 4450 feet of sedimentary rock sequence (app. 4) that in turn overlies granitic basement rocks. The sedimentary rock sequence ranging between the uppermost and lowermost units, the Coldwater Shale and the Mt. Simon Sandstone, respectively, spans Mississippian through Cambrian time, from about 360 million to more than 600 million years ago.

Three major shale units generally constitute the bedrock surface within the St. Joseph River basin (fig. 12). The slightly silty, gray to greenish-gray Coldwater Shale lies in the northeast. In much of the western and south-central parts of the basin, alternating beds of black and gray-green Ellsworth Shale form the bedrock surface. The brownish-black, noncalcareous Antrim Shale lies to the south. Detailed descriptions of these and other St. Joseph basin bedrock units are given in app. 4.

BEDROCK TOPOGRAPHY

Depth to bedrock is highly variable within the St. Joseph River basin, ranging from less than 30 feet in the Mishawaka area to nearly 500 feet in the eastern part of the basin. This variability is due to an eroded, irregular shale bedrock surface and a complex series of glacial deposits.

Bedrock elevations range from over 900 feet m.s.l. (mean sea level) in Steuben County to less than 350 feet m.s.l. near Elkhart where a deep narrow valley is present (fig. 13). Deeply incised valleys similar to the one near Elkhart are expected for other portions of the basin.

Because most water wells and test wells are completed in glacial materials, depth-to-bedrock data are lacking. Fig. 13 is therefore a generalized depiction of a diverse bedrock surface having rugged hills and V-shaped valleys.

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detect long-term water-level trends. Because most of the ground-water/lake wells have either served their intended purpose or have provided inconclusive data, two (Noble 10 and Kosciusko 8) were removed from the network in late 1986. The continuous recorder will be removed from Elkhart 6 and manual measurements will be made periodically. Funding for two of the remaining ground-water/lake wells (Kosciusko 6 and 7) has been assumed through 1987 by the City of Syracuse, after which the wells may also be discontinued. Elkhart 5 will remain in the network to monitor anticipated increases in high-capacity pumpage. Three nested wells are planned for construction near Kendallville in 1987. These wells will provide information about recharge to the deeper confined aquifer in the Kendallville area.

Piezometric Surface (Water Table)

The ground-water level within an aquifer constantly fluctuates in response to rainfall events, evapotranspiration, ground-water movement, and ground-water pumpage. Maximum fluctuations recorded at 14 in-basin observation wells average 5 feet. Because the natural fluctuations are small, static water levels can be used to approximate regional ground-water flow direction.

Static water levels used to develop the piezometric surface map for the St. Joseph River basin (Plate 2) include data for aquifers at various depths. The map represents a composite of water levels of the major aquifer systems, and it may or may not be a true representation of water levels in very shallow or very deep aquifers.

The piezometric surface map can be used to define the probable flow path of contaminants and to identify significant areas of ground-water recharge and discharge. The map can also be used to calculate expected depths to water in a well, but not to determine recommended depths of wells.

In a general way, ground-water flow approximates overlying topography and intersects the land surface at major streams. However, where thick deposits of sand and gravel occupy high topographic positions, as near Bristol (Plate 2), regional flow may not be controlled by topography.

In the St. Joseph River basin, ground-water levels range from an elevation of 1030 m.s.l. (mean sea level) in Steuben County to a low of about 670 m.s.l. along the St. Joseph River north of South Bend (Plate 2). Regional ground-water flow, which generally reflects regional topographic drainage, is toward the St. Joseph River. Ground water in southwest Steuben County, however, tends to flow out of the St. Joseph basin and into adjoining watersheds.

St. Joseph River Basin Aquifer Systems

The St. Joseph River basin presents one of the most complex geologic settings in Indiana for defining groundwater resources. The complexity is due to the impact of three major ice lobes, a thick mass of glacial drift and an irregular bedrock surface. Because of the complex glacial deposition, it is not possible in most cases to delineate discrete aquifers for any distance. Hence, seven regional aquifer systems were identified within the St. Joseph River basin (Plate 1) based on the similarities of geologic environments. These systems consist of aquifer complexes within outwash-plain, valley-train, till-plain, and intertill morainal glacial deposits. Table 11 summarizes selected hydrologic characteristics of the seven aquifer systems.

St. Joseph Aquifer System

The St. Joseph Aquifer System, an outwash plain extending from eastern Elkhart County to the basin divide in western St. Joseph County, is one of Indiana's major aquifer systems. It is composed primarily of fine to medium sand with local layers of coarse sand and gravel.

Although hundreds of well records are available to define aquifer conditions to a depth of 100 feet, little information describing greater depths is available. The St. Joseph Aquifer System is highly variable in thickness, ranging from less than 20 feet near its southern boundary to its greatest known thickness of approximately 400 feet over the buried bedrock valley at the west edge of Elkhart. Sand and gravel thicknesses of 40 to 120 feet are typical.

The main body of the outwash contains numerous interspersed thin (3 to 5 feet) layers of clay. Locally, clay deposits may extend to considerable depths, as in much of the area south of the St. Joseph River between Elkhart and South Bend. Clay deposits in an area southeast of Elkhart (Plate 1) essentially preclude significant occurrences of ground water and can make even domestic supplies difficult to obtain.

TABLE 11. Hydrologic Characteristics of Major Aquifer Systems

Aquifer System	Areal Extent (mi²)	Range of Aquifer Thickness (ft)	Common Aquifer Thickness (ft)	Range of Pumping Rates (GPM)	Common Depth to Aquifer (ft)	Hydrostatic Condition
St. Joseph	381	20 - 400	40 - 120	100 - 1500	20 - 120	confined & unconfined
Hilltop	35	10 - 100	10 - 30	25 - 150	5 - 50	confined & unconfined
Nappanee	241	3 - 30	3 - 20	50 - 600	80-90	confined
Kendallville	327	3 - 20	3 - 5	25 - 600	15 - 100	confined
Howe Outwash	243	5 - 145	15 - 50	100 - 1000	25 - 180	confined
Natural Lakes and Moraines	450	4 - 35	5 - 20	25 - 80	20 - 100	confined
Topeka	23	5 - 126	30 - 50	100 - 600	25 - 50	confined & unconfined

In the South Bend-Mishawaka area, moderately thick deposits of clay/till separate an upper deposit of sand and gravel from a deeper productive sand and gravel aquifer. The clay unit separating the upper and lower sand and gravel has an irregularly sloping surface that trends generally to the northwest. The bottom elevation of this layer ranges from about 600 feet m.s.l. near the Michigan state line to 635 feet m.s.l. in the South Bend area. Similar conditions are present east and north of Mishawaka (Plate 1), where elevations of the bottom of the clay layer are about 630 to 675 feet m.s.l. Locally, irregular clay conditions are also present in some areas north of the St. Joseph River near Bristol.

St. Joseph Tributary Valley Aquifer System

The Tributary Valley portion of the St. Joseph System encompasses valleys of the Elkhart and Little Elkhart rivers and Turkey, Solomon and Pine Creeks. These valley-train outwash systems are similar to the principal St. Joseph Aquifer System except that they often contain coarser grained deposits.

In the Goshen area and in the Elkhart River valley northwestward toward Elkhart, a well-defined sequence of surficial sand and gravel overlies a clay/till unit, which in turn overlies a confined sand and gravel aquifer. The surficial sand and gravel ranges up to 60 feet in thickness. The lower confined aquifer of this sequence ranges up to 50 feet in thickness.

South of Goshen, outwash materials of the Elkhart River and Turkey Creek-Rock Run valleys coalesce. Here the clay/till confining bed is generally absent, and thicknesses of sand and gravel exceeding 150 feet may be found.

(Turkey Creek)

The reappearance of an intermediate confining clay is noted along the Turkey Creek valley south of New Paris. The Turkey Creek Aquifer System is typified by the hydrogeology of the Milford area, where characteristic surficial sand and gravel overlie localized clay/till lenses and a lower confined sand and gravel aquifer.

Thicknesses of surficial sand and gravel units commonly average 40 feet, but may range from 10 to 100 feet. Outwash sands and gravels are thicker in the Turkey Creek System than in areas to the north, and in broader portions of the valley commonly range from 50 to 100 feet in thickness. A subsurface clay/till zone is frequently encountered at an elevation ranging from 750 to 820 feet m.s.l. While the approximate thickness of the clay/till zone is variable, it apparently thickens toward the edges of the Turkey Creek System. Although localized clay/till lenses contained within the outwash are normally thin, thicknesses of 25 to 50 feet have been reported.

A deeper 5- to 75- foot thick sand and gravel aquifer complex is frequently encountered at an elevation of 740 to 770 feet m.s.l. This aquifer complex is locally confined beneath the clay/till zone, and is probably interconnected with thick sequences of surficial sand and gravel. The deeper sand and gravel unit extends laterally to the west into the Nappannee Aquifer System and to the east into the transitional portion of the Natural Lakes and Moraines Aquifer System.

A few water wells have penetrated a third deep sand and gravel zone at elevations between 690 to 720 feet m.s.l. This zone is confined by a lenticular clay/till layer. Only the thickest sequences of surficial sand and gravel may intersect this deeper aquifer locally. The lateral extent of the deepest aquifer complex is not known; however, a few wells in the transitional and main parts of the Lake and Moraine System encounter aquifer material at the same elevation range as the deepest Turkey Creek aquifer complex.

Ground-water levels in the surficial outwash sand and gravel deposits are normally shallow, and static water levels are less than 10 feet below ground surface. Near the boundaries of the aquifer system, static water levels deepen to nearly 40 feet.

Thicker deposits of this aquifer system can be expected to yield 500 to 1000 gpm per well. A few scattered high-capacity wells south of Milford along Coppes Ditch have reportedly produced 750 to 1350 gpm during brief pumping tests.

(Solomon Creek)

The Solomon Creek Tributary Valley Aquifer System is composed of thick layers of outwash sand and gravel with interbedded clay layers. Data for this system are sparse, but the aquifer appears to be less complex than the Turkey Creek System. From its junction with the Elkhart River, the Solomon Creek System trends in a southeasterly direction. Thicknesses of sand and gravel units average 60 to 70 feet but vary from 20 to 160 feet. Greatest thicknesses occur southeastward of the Elkhart-Kosciusko County line where up to 104 feet of saturated sand and gravel deposits have been found. Sand and gravel thins in the southeastern portion of the system.

In the area of Wolf Lake, clay layers become more common in the system and increase in thickness. Whereas the sand and gravel occurs as one thick unit to the northwest, in the Wolf Lake area several sand and gravel layers generally are separated by clay zones of variable thickness.

Generally the Solomon Creek Aquifer System is capable of yielding 300 to 1000 gpm from individual wells; however, some wells near the Noble-Elkhart County line have yields of over 1200 gpm. High-capacity yields may not be possible in areas within the aquifer where localized thick clay deposits are present, such as in some areas between Benton and the Elkhart-Kosciusko county line. Well depths generally average 50 feet, but may range up to 250 feet.

(Pine Creek)

Although little is known about the Pine Creek-Rock Run Aquifer System, this tributary valley outwash system is potentially the most complex. Morainal deposits have blocked the lower reaches of this valley where it merges with the St. Joseph Aquifer System, and have substantially modified the surface appearance of the Pine Creek valley. Where data are available, sand and gravel is a major component of the materials contained within the valley. Deeper sand and gravel is expected to underlie a clay layer which in turn underlies the surficial sand and gravel. The outwash contained within the Pine Creek valley may be related to the materials deposited in the Turkey Creek valley. It is expected that moderately high producing (300 to 600 gpm) wells could be developed in the Pine Creek Aquifer System.

(Little Elkhart River)

The Little Elkhart Aquifer System originates northwest of Topeka in LaGrange County, where outwash deposits of surficial sand and gravel are found in the valleys of Little Elkhart River and Rowe-Eden Ditch. The sand and gravel deposits, which range up to 50 feet in thickness, overlie a thick clay sequence which may, in turn, overlie a deeper sand and gravel aquifer sequence. Data in the southeastern part of the valley system are quite limited.

Southeast of Middlebury, the valley system becomes more defined and outwash sand and gravel deposits up to 60 feet in thickness can be found. At Middlebury the surficial sand and gravel is underlain by a 50- to 60- foot clay/till layer that separates the upper aquifer from a deeper sand and gravel deposit that locally exceeds 60 feet in thickness. The elevation at the bottom of the confining clay unit is about 730 to 740 feet m.s.l. at Middlebury, and probably declines to the northwest.

Wells completed in the Little Elkhart System typically can be expected to yield 500 to 1000 gpm to properly constructed, large-diameter wells.

Topeka Aquifer System

The Topeka Aquifer System, characterized by thick surficial deposits of outwash sands and gravels, is bounded on all sides by the Natural Lakes and Moraines Aquifer System. Along the gradational system boundaries, surficial sands and gravels thin and interfinger with clays of the Natural Lakes and Moraines System.

The Topeka Aquifer System consists of two separate areas that are geologically similar. The main (western) portion, located near the town of Topeka, is composed of surficial sand and gravel deposits up to 126 feet in thickness, but having common thicknesses of 30 to 50 feet. Interbedded clay layers up to 10 feet in thickness, occasionally found in the main system, become thicker and more common near the aquifer system boundaries. Static water levels in the unconfined surficial sand and gravel deposits are generally 25 to 50 feet. Yields from shallow unconfined wells are unknown due to limited data.

A deeper confined aquifer underlies the main Topeka system, commonly at an elevation of about 850 feet m.s.l. This deeper system may be related to the Natural Lakes and Moraines Aquifer System. A primary sand and gravel deposit comprising the deeper Topeka aquifer is up to 20 feet in thickness and seems to be continuous throughout the Topeka system. Other minor sand and gravel layers are locally present in clays underlying the surficial outwash deposits, but do not appear to be laterally extensive or continuous.

The main Topeka Aquifer System is used by several high-capacity irrigation wells. These wells are usually from 120 to 160 feet deep and produce water from confined or semi-confined sand and gravel aquifers beneath clay layers. Reported well yields range from 1000 to 2000 gpm. Although these yields are greater than can normally be expected, properly constructed,

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3 MAPS OF ST. JOSEPH RIVER BASIN

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Appendix 4. Bedrock sequence* underlying the St. Joseph River basin

System/Series	Rock Unit	Thickness in meters (feet)	Description
Quaternary: Holocene, Pleistocene		15-150 (49-490)	Unconsolidated material
Mississippian	Coldwater Sh.	50 (165)	Shale: gray to greenish-gray, slightly silty
	Sunbury Sh.	3 (10)	Shale: black
	Ellsworth Sh.	12-60 (39-196)	Shale: alternating gray-green and black in bottom part; grayish-green and containing some limestone dolomite lenses in top part
Devonian	Antrim Sh.	18-66 (59-216)	Shale: black, fissile; greenish-gray shale in places in lower third; pyrite common in bottom part
	Traverse Fm.	6-37 (20-121)	Limestone and dolomitic limestone: brown, tan and gray, very fine grained to coarse grained, biofragmental; light-colored to tan fine-grained oolitic dolomitic limestone common in top part
	Detroit River Fm.	5-50 (16-164)	Limestone and dolomite: mostly tan to gray, variably fine grained, argillaceous, bioclastic, sublithographic, and, in places, brecciated and mottled; contains a gray to tan fine-grained argillaceous dolomite in lower part and a tan lithographic limestone near the top
Silurian	Wabash Fm.	30-61 (98-200)	In upper part, limestone and dolomotic limestone: light-colored, granular, fossil-fragmental, cherty, slabby bedded. In lower part, dolomotic siltstone and silty dolomite: gray, dense to fine-grained, argillaceous, thick-bedded to massive. Carbonate bank, reef, and reef-detrital facies throughout, mostly dolomite: light-colored, granular, vuggy, notably fossiliferous
	Pleasant Mills Fm.	37-91 (121-298)	Dolomite and dolomitic limestone: light-, medium-, and dark-brown, dense to medium-grained; finely vuggy in part, algal laminated in part
	Salamonie Dol.	45-80 (148-262)	In upper part, mostly fairly pure dolomite: light-colored, granular, vuggy, very porous, partly reefy. In lower part, mostly dolomite: gray and tan, dense to fine-grained, argillaceous, partly cherty

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